TENTACULITIDS FROM NEW SOUTH WALES, AUSTRALIA

By Kathleen Sherrard
Centennial Park, Sydney, N.S.W.

Abstract

Tentaculitids found in New South Wales are described and classified according to their structure, determined microscopically where their state of preservation allows. *Tentaculites ornatus* Sowerby occurs in Silurian (Wenlockian) strata at Yass. *Tentaculites chapmani* n sp. and *Nowakia* aff. *acuaria* (Richter) occur together in Lower Devonian limestone at Ravine on the Yarrangobilly River, in the Garra Formation at Wellington and in the Taemas Stage of the Murrumbidgee Series near Taemas Bridge.

aff. *Volynites russiensis* G. Ljaschenko and *Nowakia* aff. *acuaria* (Rich.) are recorded together from limestone of either Silurian or Devonian age at Eurimbula; the former is recorded from a bore at Louth, and from the Manildra Formation of Upper Silurian age at Cudal. A table summarizing these occurrences is included.

Tentaculitids from other localities are described generically, but cannot be placed specifically because of poor preservation.

Tentaculitids are recorded from one bore. Other specimens are from surface outcrops.

Introduction

Tentaculitids have been found in most countries, the oldest having been recorded from the Ordovician (Tremadocian) of the United States (Fisher & Young 1955). They are widespread in rocks of Silurian and Devonian age and become extinct in the Late Devonian; they occur in Silurian and Devonian strata in New South Wales.

Tentaculitids are small, sharply conical annulated shells, varying in length from a few millimetres up to several centimetres. They are not attached to any foreign body and are usually straight, though a number of those studied in this work have their proximal tips slightly bent. The shell walls vary in thickness from about 0·2 mm to 0·01 mm.

A study of New South Wales tentaculitids was undertaken with the objects of describing them, and of determining their usefulness for zoning the formations in which they occur. A zonation table cannot be set up until a taxonomic and stratigraphic analysis is performed. This paper initiates such a study.

Among the few previous references to tentaculitids from New South Wales is a listing by W. B. Clarke (1860, p. 286) of *Tentaculites ornatus* (identified apparently by Salter), *T. annulatus* and *T.* ? *tenuis*. Localities and authors are not mentioned.

In 1881, R. Etheridge Jr. described and figured a tentaculitid which had been found by Professor Liversidge at 'Holmes Paddock on the Macquarie below Wellington'. Two specimens from this locality, one of which is now registered as PG 4513, were among a group of fossils presented by Liversidge to the British Museum.

W. S. Dun (1898) described and figured *Tentaculites* cf. *bellulus* Hall which had been obtained from boulders at White Cliffs opal fields, and E. D. Gill (1940), when describing a trilobite from Cootamundra, recorded among other fossils from the same locality, *Tentaculites* aff. *tenuis* Sowerby. The specimens from these localities are referred to again in this paper.

Stratigraphic Value

After careful study of the group, the Russian palaeontologist G. Ljashenko (1959, p. 140) considers '*Tentaculites* answer the essential demands required of a fauna which will be of value for stratigraphy'. She states (p. 147) that certain species are restricted to a fraction of a stratigraphical zone in the U.S.S.R. and thus different horizons are characterized by different species of tentaculitids. They are not confined to a particular lithological type and occur in large, often enormous, numbers from littoral to deep-water facies. Fossils such as goniatites or brachiopods, which have been used as zone fossils, may be found only in certain rock facies. As tentaculitids seem not to be so restricted (Ljashenko 1965, p. 98) they appear to be more useful as zone fossils.

Ljashenko made use of tentaculitids to work out a detailed sub-division of the Devonian deposits of the Central and Eastern Districts of the Russian Platform. She gives tables (1959, p. 138; 1965, p. 100) with eighteen to twenty divisions in the Devonian each characterized by one or more different species of *Tentaculites, Nowakia, Styliolina*, etc. (The spelling of the word as '*Nowakia*' has priority over '*Novakia*' (Prantl and Bouček, 1960), though the spelling '*Novakia*' is used by Ljashenko in fossil names given in Latin script in her Russian texts. She transliterates her own name as author of a species she is describing, to 'Ljashenko'. Therefore that spelling is used here.)

Tröger (1959) pointed out that in East Thuringia, tentaculitids are the most common macrofossils in the Upper Silurian and the Devonian and that since there is a regularity in the distribution of individual species, they could be used for the classification of the rocks of these ages. He drew up a short table.

Bouček and Prantl (1960) suggested the use of tentaculitids as zone fossils in Bohemia instead of goniatites which serve for characterizing the sub-divisions of the Lower Devonian (Gedinnian, Siegenian and Emsian) of the Rhenish geosyncline, since the goniatites have proved unusable in Bohemia. They pointed out that tentaculitids are particularly suitable in the classical Barrandian area because quite a different association of tentaculitids appears in the Dvorce-Prokop limestones above the Silurian-Devonian boundary from that in the Lochkov limestone below it (p. 94). They also remarked that different species of tentaculitids (*Nowakia*, etc.) characterize different formations in the Lower and Middle Devonian.

Bouček's 'The Tentaculites of Bohemia' (1964) is a study of the tentaculitids occurring in Silurian and Devonian limestones and shales. A few were described by Barrande (1852, 1867) and some others by Novak (1882). Bouček's work revises earlier determinations and describes new species—thirty-eight in all. These are all thin-walled, presumably pelagic forms, whereas in New South Wales and on the Russian Platform, both thick-walled *Tentaculites* and thin-walled *Nowakia* have been found (sometimes together on the same slab in New South Wales, see Pl. 38, fig. 13). By the use of these thin-walled forms, Bouček has been able to sub-divide the Upper Silurian and Lower and Middle Devonian into twelve zones each characterized by different species. It has yet to be determined whether these zones can be found in the Silurian and Devonian in other countries.

Zagora (1962, 1964) taking the 'classic researches of Rh. Richter (1854) and O. Novak (1882) as basic', has redescribed thin-walled tentaculitids from Thuringia, and having investigated their stratigraphic occurrences, has found that a number of zones can be set up in the Upper Silurian and Devonian, each characterized by different assemblages of tentaculitids.

Zoological Affinities and Classification

The correct zoological classification of tentaculitids is uncertain because nothing is known of their soft parts nor of the relationship of their shells to animals living today.

By various authors, at different times, they have been placed among brachiopods, foraminifera, annelida, echinodermata, gasteropods and pteropods and even in other groups. There has been no general agreement about any of these allocations.

Thomas Austin's view (1845) that they were pteropods was generally adopted after that date, though sometimes without conviction. Giving no evidence, he wrote 'on a careful examination of numerous specimens I am of opinion that the *Tentaculite* is the shell of a Pteropodous mollusk allied to the recent *Creseis* as the *Conularia* is that of an animal allied to the *Cleodorae*'.

An argument against their being pteropods was the long gap in time between the dying out of tentaculitids in the Devonian and the appearance of fossils universally accepted as pteropods in the Tertiary. Further, the thick shells of *Tentaculites* (*s.s.*) are quite unlike those of most pteropods. The remarks of R. Etheridge Jr. (1881) against this allocation are recorded later.

W. B. Clarke (1860) placed them in the Annelida, as did some other workers. The straight shells of tentaculitids and their mode of living unattached to foreign objects are some of the factors cited against these shells being formed by worms. The extinction of tentaculitids in the Late Devonian also seems to argue against their being formed by tubicolous worms which continue until the present day.

G. P. Ljaschenko (1955, 1957, 1958a, 1959) set up a new class, the Coniconchia, as a result of her exhaustive study of Devonian tentaculitids obtained from surface outcrops and from sub-surface cores in the U.S.S.R. She has also studied a small number of Silurian tentaculitids (1958b). The new class Coniconchia contained two super-orders, Tentaculitoidea and Hyolithoidea. The superorder, Tentaculitoidea, was divided into the orders, Tentaculitida, Styliolinida and Novakiida. The class, Coniconchia, was referred to the Mollusca (?) (Ljaschenko 1957, p. 84), but in the diagnosis given at the beginning of her 1959 volume, it is referred to Mollusca without query.

Fisher (1962) disagreed with the placing of hyolithids and tentaculitids in a single class as Ljaschenko had done and he set up a new class of the Mollusca, the Cricoconarida, comprising the orders, Tentaculitida and Dacryoconarida. He pointed out that there are already in use many variations of the word 'tentacle' for unrelated animals and that a new word, Cricoconarida, avoids confusion. He uses the word, Tentaculitida for the name of an order, because of previous broad usage, especially by Ljaschenko. He placed hyolithids and related forms in a new class, the Calyptoptomatids.

Bouček (1964) rejected Fisher's new class name, Cricoconarida, introducing yet another name, Tentaculita. He considered that the use of a traditional name would cause no confusion. He retained Fisher's ordinal names and added three others. Bouček separated the orders mainly on the character of the shell wall and on the nature of the embryonal chamber.

I have followed Bouček's ordinal classification in this paper, but am describing representatives of two orders only, the Tentaculitida G. Ljaschenko 1955 and Dacryoconarida Fisher 1962.

The Tentaculitida possess shells with relatively thick multi-layered walls. The outer layers are transversely folded into annulations and are pierced, partway, by canals. The inner layers are smooth or only slightly annulated and are not pierced.

Bouček (1964, p. 51) states 'longitudinal striation is not developed', but I have seen some indication of longitudinal markings in specimens having a conical initial chamber, mentioned later in this paper.

The Dacryoconarida have shells with very thin walls which are not pierced by canals. The walls are bent into rippling transverse swellings and contractions which may be repeated on the internal surface. Longitudinal striations are often present. The initial chamber is tear-drop like.

The sub-ordinal classification of Ljaschenko (1958a) is followed in this paper. Families are separated according to the situation of the annulations, whether they are uniform or non-uniform; sub-families on the thickness of the shell-wall and the character of the internal cavity. Genera and species are separated according to finer features and details of sculpture.

In members of the family Tentaculitidae Walcott 1886 described in this paper, there are annulations of different sizes and the arrangement of these with respect to one another distinguishes the genera.

The only member of the order Dacryoconarida Fisher 1962 described here has the characters of the order.

Glossary of Terms

Tentaculitid signifies any member of the Class Tentaculita Bouček 1964.

Angle of growth, as used in this paper, is the angle between the sides of the conical shell which contained the main body of the animal, that is, between the shell walls as they approach the aperture.

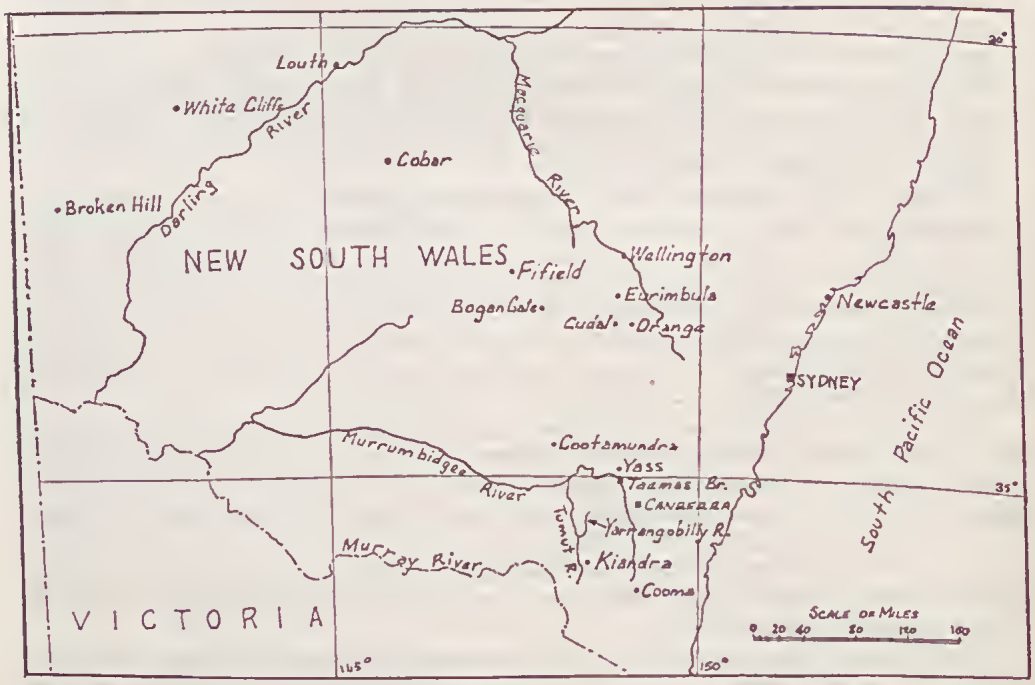

FIG. 1—Locality Map of New South Wales.

Annulation describes the large, parallel ring-like protuberances circling the shells of members of the order Tentaculitida G. Ljaschenko 1955.

Cast is used to indicate the material which replaced the body of the original animal and which carries its markings.

Mould means the cavity from which the body of the animal has been dissolved.

Riblets are the small, fine rings between the annulations.

Striations are longitudinal flutings on the shell.

Swellings and **Contractions** are the transverse billowing ripples on the shells of members of the family Nowakiidae Bouček and Prantl 1960.

Ecology

Members of the Tentaculitidae Walcott 1886 and Nowakiidae Bouček and Prantl 1960 have been found in New South Wales. Tentaculitidae have been sometimes found alone and sometimes with Nowakiidae. Nowakiidae have not been found alone, but no conclusion can be drawn from this fact, because tentaculitids have, as a rule, been collected only incidentally to other fossils and little intensive search for them has been made. Findings have been made in surface outcrops of limestone, sandstone, siltstone and quartzite, and in one case from a bore through calcareous shale.

Most of the tentaculitids described here came from limestones with associated brachiopods, corals, crinoids, ostracods, etc. Nowakiids have been found only in limestones.

The most prolific occurrence of tentaculitids yet seen in New South Wales is at Cootamundra in a fine-grained white to yellowish-green Silurian siltstone. Unfortunately they are almost invariably found as moulds. When occurring in large numbers, the tentaculitids are alone, but in other specimens of the same rock from Cootamundra, a few occur with brachiopods, lamellibranchs, trilobites, etc. (Gill 1940; Sherrard 1960).

In several cases in western New South Wales, traces of tentaculitids have been found as moulds or, rarely, as replacements in sandstone or quartzite.

Observers have frequently remarked on the lack of relationship of tentaculitids to facies, thus making them potential zone-markers. However, Bouček (1964, p. 157) discusses 'the serious problem' of the simultaneous occurrence of thick- and thin-walled tentaculitids in some rocks. The former should be limited to an environment which, though on the sea floor (or benthonic) is only of shallow depth and therefore rich in oxygen, while the latter are typical of different conditions. He admits, however, that thin-shelled forms are not absent from shallow benthonic areas. Conditions in New South Wales where thick- and thin-shelled tentaculitids occur together (Pl. 38, fig. 13), though not in vast numbers, seem to illustrate such a shallow, benthonic environment.

Fisher (1962) suggests that the Tentaculitidae were nekto-benthonic while Nowakiidae were planktonic.

Though tentaculitid shells in the rocks here examined lie generally on parallel planes, this is not always the case. Polished slabs and thin sections of limestones show both longitudinal and transverse sections of tentaculitids lying beside each other (Pl. 38, fig. 8). This condition contradicts a statement of Fisher (1962, p. 104) that 'Cricoconarid shells always lie parallel to bedding of strata that enclose them . . . this strongly denies a fossorial habit'. Conditions on coral reefs, from which some of these tentaculitid-bearing limestones probably come, might cause tossing about of shells after the death of the animal, resulting in a final

random arrangement. Such conditions also probably caused the insertion of smaller shells into larger ones (Pl. 37, fig. 2, 3).

Study of Tentaculitids

To classify tentaculitids, it is necessary to study their shell-walls, both externally and internally, their thickness, structure and seulpture. The walls may be smooth, annulated or rippled externally with the internal surface either repeating this sculpture, or smooth. Vertical striations may appear. The walls may consist of several layers with some layers repeating annulations on the surface and some not doing so. Canals may partly pierce the walls. The initial chamber may be conical in form or rounded. The character of the internal eavity, the presence or absence of septa in it and the angle of growth of the shell must be known.

It is therefore neeessary to prepare thin sections, polished surfaces, or enlarged photographs, showing longitudinal and transverse seetions, to determine the distinguishing characters of the fossils.

In the study of New South Wales tentaculitids, most information has been gained where the fossil replacing material has been calcite. Little or nothing has been learned from empty moulds formerly occupied by tentaculitids, nor from some specimens where the material replacing the fossil is silica or clay.

Systematic Descriptions

Class TENTACULITA Bouček 1964

Order TENTACULITIDA G. Ljaschenko 1955

Family TENTACULITIDAE Waleott 1886

Genus **Tentaculites** Schlotheim 1820

The members of this genus possess narrowly conical shells whose seulpture consists of rather distant transverse annulations. Spaces between these are often covered by fine riblets, chiefly developed in the second part of the shell.

Tentaculites chapmani n. sp.

(Pl. 37, 38, fig. 1, 3, 4, 5, 6, 7, 12)

Tentaculites liversidgei Eth. fil.; Etheridge, R. Jr.; J. & Proc. Roy. Soc. N.S.W., 1881 (for 1880), xiv, 255 (*nomen nudum*).

Tentaculites sp. Eth. fil. ibid unnumbered plate, fig. 10, 10a.

HOLOTYPE: No. F43436, Australian Museum.

DESCRIPTION: The shells are of medium size, usually about 10 mm or slightly longer, straight, narrowly eonieal and of eireular cross-seetion. Their surfaecs are covered with regularly arranged, parallel, raised, transverse annulations of blunted, sometimes almost thorn-shaped triangular eross-scetion, projecting from the shell for a distance equal to about one-seventh (in the youthful stage) to nearly one-half (in the mature section) of the internal diameter of the shell. The annulations can be seen in section to slope with a slightly greater (that is flatter) angle baekward to the apex than forward to the aperture.

The inter-annular areas are semi-eireular near the apieal end, where they are about equal in width to the annulations. They are flatter in more mature sections of the shell and the space between annulations gradually increases by about three times. Riblets are either absent or very faint on inter-annular areas near the apex, but five or six can sometimes be counted on those near the aperture. Traces of longitudinal striations can be seen on some inter-annular areas.

The wall of the shell varies in thickness from about one-seventh to one-twelfth the internal diameter of the shell (that is to nearly 0·1 mm). Its internal surface is nearly smooth in the early section of the shell but later becomes annulated, repeating the external sculpture in the apertural fifth of the shell. The wall is layered with the outer layers forming the outer sculpture while the inner layers are more nearly smooth (Pl. 37, fig. 1). There are about five layers. Thin canals, more than forty per mm, pierce the wall of the shell. They pass inward at right angles to the surface, reaching about one-third of the way to the internal surface.

Thick septa (0·1 mm wide) can be seen in very well-preserved specimens in the apical cavity (Pl. 38, fig. 4). They are horizontal near the apex, but become increasingly concave with a basin-shaped concave surface opening towards the aperture. As many as twelve have been counted.

A conical embryonal chamber forms the proximal end of the shell. There is a slight thickening of its wall, forming a constriction about one mm from the apex. The apex has a smooth internal and external wall (Pl. 38, fig. 7). The tip of the apical section is usually straight, though it may sometimes be bent or broken off. It is up to 1·3 mm long and 0·1 mm wide.

DIMENSIONS: Length of shell: usually up to 12 mm, exceptionally to 22 mm. Width: Apertural 0·8 mm to 1·0 mm, exceptionally to 1·3 mm. Angle of growth: about 5°.

LOCALITIES: Tentaculitids from five localities in N.S.W. are considered to belong to this species. Locality of holotype: Ravine, about Portion 57, Par. Selwyn, near the Yarrangobilly R., about eight miles NW. of Kiandra (also known as Upper Lob's Hole). Other occurrences: The Holmes, about Portion 36, Par. Mickety-mulga, near Macquarie R., about 9 miles downstream from Wellington; Macquarie Park, Portion 103, Par. Ponto on the opposite side of the river from the last locality (in the Garra Formation, Strusz 1965); Portion 65, Par. Taemas, W. side of Murrumbidgee R., 14 miles SW. of Yass, in the Taemas Stage of the Murrumbidgee Series (Browne 1959) (this is the locality named 'Shearsby's Wall-paper' by T. W. E. David, when A. J. Shearsby showed him a vertical cliff of limestone covered with fossils); Portion 208, Par. Warroo, near Taemas Bridge over the Murrumbidgee R. and on the opposite side of the river from the last locality.

REMARKS: Tentaculitids from the second of these localities, The Holmes, were among other fossils presented by Liversidge of Sydney University to the British Museum and described by R. Etheridge Jr., 1881. Of the two presented, one is now listed at the British Museum (Natural History) as No. PG 4513. Etheridge concluded his partial description of the tentaculitids, which mainly referred to the structure of the shell, by saying 'should this *Tentaculites*, on further examination, prove to be specifically distinct from the numerous ones which have hitherto been described, I would propose for it the name *T. Liversidgei*'. This is undeniably a *nomen nudum*. Hence a holotype has been selected from elsewhere, since although it is more than 80 years since Etheridge wrote, precise comparison of the original tentaculitid specimen with others, to determine if it is specifically distinct is still not possible. Except in the case of those described by Ljaschenko, the internal structure of *Tentaculites* has not been recorded. Conspecific relations cannot therefore be recognized and the validity of Etheridge's nominal species cannot be demonstrated.

The two illustrations of the tentaculitid which Etheridge partially described (Fig. 10 & 10a) are on an unnumbered plate accompanying his paper but are listed in the Explanation of Plate on p. 258 of Volume xiv of the J. & Proc. Roy. Soc. N.S.W. as of *Tentaculites* sp. and not of *Tentaculitids liversidgei*. Fig. 10

represents a number of tentaculitids on a slab of rock which exactly match neither specimen No. PG 4513 now in the British Museum, nor specimen No. F688 in the Fossil Catalogue of the Mining Museum, Sydney, registered as *Tentaculites liversidgei* Eth. f. from Holmes Station Paddock, Wellington (Pl. 38, fig. 5).

The present owners of the property, Mr and Mrs G. B. H. Sutherland, have kindly informed me that 'The Holmes' station was taken up about 1870 by J. A. Gairdner and consisted of portions in the Par. of Micketymulga on the N. bank of the Macquarie R., downstream from Wellington. Limestone outcrops in portions 107, 35 and 36 within what was 'The Holmes' station. The same rock, of the Garra Formation (Strusz 1965) can be traced on the S. bank of the Macquarie in Portion 103, Par. Ponto. Thin sections of this limestone show the same structure as that referred to by Etheridge in his paper of 1881.

He noticed (p. 254) that in thin section 'the shell wall was distinctly traversed by small tubuli from the exterior . . . these . . . do not penetrate quite through the shelly matter . . . I have not observed any trace of septa . . . The internal and external walls of the shells . . . correspond with one another . . . In one or two examples there does appear to be a division of the shelly matter into laminae . . . If the structure exhibited by Australian *Tentaculites* should prove to be constant throughout the genus, it showed little in common with that of a *Pteropod*.'

At the time Etheridge was writing, tentaculitids, as a rule, were considered to be pteropods. His observations on the wall structure correspond with those made by G. Ljaschenko (1959), but he missed seeing septa within the internal cavity, probably because of poor preservation of the specimens.

Comparison: *Tentaculites chapmani* n. sp. resembles the description given by G. Ljaschenko (1959, p. 75) for the first group of the genus *Tentaculites* Schlotheim, em. G. Ljaschenko 1954. Species in this group show large transverse rings separated by wide inter-annular areas which are smooth in the first half of the shell and usually covered with transverse riblets in the second. The internal surface of the wall is smooth in the first half of the shell and ringed in the second. *T. maslovi* G. Ljasch. from the Givetian is cited as an example of this group and from its description shows similarities with *T. chapmani* n. sp. though *T. maslovi* is considerably smaller.

Material: From all localities except 'The Holmes' and Portion 208, Par. Warroo, at least 100 specimens of *T. chapmani*, distributed on different rock specimens from each. From 'The Holmes' one specimen which contains about twenty tentaculitids. From Portion 208, Par. Warroo, one large specimen with 100 examples of *T. chapmani*. The specific name has been chosen to commemorate the name of Frederick Chapman, palaeontologist.

Tentaculites ornatus Sowerby

(Pl. 37, fig. 2)

Description: The shell is of medium size, not more than 10 mm long, straight, narrowly conical, and of circular cross-section. In the apertural section its surface is covered with large, regularly arranged, parallel, transverse, raised annulations of rounded cross-section (Pl. 37, fig. 2). These are separated by inter-annular areas of semi-circular shape in the apical part of the shell, 1 to 1½ times as large as the annulations. In the more mature part of the shell, the inter-annular areas become flattened and are from 2 to 5 times as wide as the annulations. Riblets numbering 4 to 6 or more sometimes cover the inter-annular areas but cannot always be seen. Longitudinal striations can also sometimes be traced on these areas. The wall is

about $\frac{1}{10}$ the thickness of the internal diameter of the mature part of the shell. Its internal surface is nearly smooth, only faintly repeating the external sculpture opposite the annulations. The annulations are smoothly rounded when seen in longitudinal section, standing out from the shell up to about ⅓ of its internal diameter, but usually less. In the size of the diameter in both youthful and mature parts of the shell (0·1 and 0·9 mm respectively) there are one to two annulations. The wall has three layers, which follow the external contour of the shell. They are pierced by vertical canals about 0·02 mm distant from each other. The apical end may be slightly bent. There is a total of about 20 annulations. Septa are present.

DIMENSIONS: Length of shell: Not more than 10 mm. Width of shell: 1·0 mm near apperture, 0·1 mm near apex. Angle of growth: About 6°.

LOCALITY: Hatton's Corner, Portion 7, Par. Hume, Yass.

AGE: Wenlock, Silurian (Brown & Sherrard 1951).

MATERIAL: A hand-specimen of limestone in which about one tentaculitid occurs to the square cm.

REMARKS: Tentaculitids found at Hatton's Corner agree well in dimensions with those in a specimen of *T. ornatus* Sowerby from the Wenlock of Dudley, England (Australian Museum specimen No. F31534) and with the dimensions given in McCoy's (1855) description of *T. ornatus* Sowerby from the same locality. They are much smaller, however, than *T. ornatus* Sowerby described by G. Ljaschenko (1958b) from deposits in the Podolia districts of the U.S.S.R. 'belonging to the uppermost part of the Ludlow stage', though both show the rounded annulations characteristic of *T. ornatus*.

Tentaculites sp. No. 1

(Pl. 38, fig. 10, 11)

DESCRIPTION: The shell is large, up to 18 mm long, straight, narrowly conical, of circular cross-section. The surface is covered with regularly arranged parallel, asymmetric annulations of gradually increasing size and blunted triangular cross-section. The annulations are separated from each other by inter-annular areas nearly equal to them in size and of shallow crescentic form. A gradual increase in size and a flattening of the outline of these areas takes place towards the aperture. The angle of slope of the annulations is noticeably flatter apically. In the mature section, the annulations are rostrate. In this portion of the shell, the annulations project to a distance of ⅓ the internal diameter in some specimens. Fine riblets are seen on both upper and lower edges of each annulation as well as on the inter-annular areas (Pl. 38, fig. 11). Vertical striae make a faint cross-hatched pattern with the horizontal riblets on the shell's surface.

Wall-thickness varies from one-quarter to one-eighth of the internal diameter of the shell. Generally, the layered wall has a smooth internal surface though it is slightly annulated near the aperture. Partitions can be seen in the apical cavity.

DIMENSIONS: Length up to 18 mm; width up to 1·3 mm at the aperture, 0·25 mm near the apex. Angle of growth about 5°. Three large annulations and seven riblets occur in 1·3 mm (the size of the apertural diameter). Three annulations in 0·25 mm near the apex. Total: 45 annulations.

LOCALITY: ? Cavan, near Taemas Bridge, over the Murrumbidgee R., 14 miles SW. of Yass.

MATERIAL: One large slab, with sixty or more tentaculitids and a large '*Orthoceras*' like nautiloid. Sydney University Geological Collection No. 5891.

REMARKS: The shape of the coarse annulations in the mature section of this shell is distinct from that of any others from New South Wales so far studied, with the exception of the annulations in a tentaculitid fragment found in limestone in Portion 107, Par. of Micketymulga, near Wellington. However, a new species cannot be erected since locality is uncertain. The shape and arrangement of the annulations, the wall-thickness of the shell and its smooth internal surface suggest a comparison between this tentaculitid and *Uniconus* G. Ljaschenko, particularly with the species *Uniconus livnensis* G. Ljaschenko. But the presence of riblets on the inter-annular areas excludes this fossil from the genus *Uniconus*. This tentaculitid is also larger than any *Uniconus* described by Ljaschenko. It shows some similarity to *Dicricoconus orientalis* (Karpinsky) (G. Ljaschenko 1959, Pl. X; Fisher 1962, p. 114). That species, however, does not show fine riblets either. The fossil being described is retained for the present in the genus *Tentaculites*, but it may need reassignment later. It is possible it may be older than *T. chapmani*.

Tentaculites sp. No. 2

Tentaculites cf. *bellulus* Hall; Dun, W. S., 1898. Rec. Geol. Surv., N.S.W., 5: 160, Pl. xviii, fig. 9, 10.

DESCRIPTION: *Tentaculites* cf. *bellulus* Hall was recorded by Dun (1898) from white saccharoidal quartzite of Devonian age occurring as inliers in Cretaceous rocks at White Cliffs opal fields. Brachiopods, lamellibranchs, gasteropods and cephalopods are also present. The tentaculitids, for the most part, occur as empty moulds, though occasional fragments of silicified replacing material remain. The moulds are of shells up to 20 mm long and 1 mm wide at the aperture. Coarse transverse annulations are arranged at regular distances (about 2 in the width of the apertural diameter) and protrude about ⅓ of the total width. Riblets may be seen on the inter-annular areas.

The shells have extremely strongly developed longitudinal striations which make deep indentations on the annulations and are noticeable on the inter-annular areas also. They are much more noticeable than any of the riblets seen in tentaculitids already described in this paper. This difference may be due to the type of replacing material.

Dun does not give his evidence for assigning these tentaculitids to *T. bellulus* Hall. I cannot agree with this identification. Hall (1879, p. 169) does not mention longitudinal ornamentation in his diagnosis of *T. bellulus*, nor is it to be seen in his figure of the species. I must also differ from Dun's statement 'there appears to be little or no trace of transverse striation between annulations'. This shows clearly on plaster casts made in the moulds of tentaculitids from White Cliffs. Dun goes on to say 'there is some general resemblance to *T. ornatus* Sowerby'. The state of preservation of the specimens will allow an identification only as *Tentaculites* sp.

MATERIAL: White quartzite slabs, each with about twenty moulds of *Tentaculites* sp. in the Australian Museum and in the Sydney University Geological Collection. Moulds of tentaculitids and lamellibranchs occur also in a similar white saccharoidal quartzite found about half-way between Louth and Cobar, about 150 miles E. of White Cliffs (No. F11753, Mining Museum, Sydney). They resemble those from White Cliffs in size and longitudinal furrowing.

Tentaculites sp. No. 3

MATERIAL: Tentaculitids in the Bogan Gate Sandstone of the Hervey Group (Conolly 1965) from Central New South Wales have been examined from two localities, 12 miles NNW. of Bogan Gate and 12 miles ESE. of Fifield (Mining

Museum, Sydney, specimens F9785, F9787). The tentaculitids occur as moulds and casts in red sandstone which also contains moulds and casts of brachiopods.

Conolly (1965, p. 80) writes that the rocks containing these fossils are 'assumed to be of Late Middle Devonian to Early Upper Devonian age'. Material examined consisted of two slabs from each locality, each with about 20 specimens.

DESCRIPTION: This *Tentaculites* is rather broader (up to 1·4 mm) at the aperture than that found at White Cliffs and the annulations are not arranged so regularly (about 2 per size of the apertural diameter). Between them on the flat inter-annular areas are very well-marked fine transverse riblets (7 per size of the apertural diameter). The tube forming the apex is covered with fine transverse riblets throughout its length of 2·5 mm. The shells are up to 17 mm long. Well-marked longitudinal striations are also present, but are perhaps not so strongly marked as in tentaculitids from White Cliffs. The difference may be due to the type of replacing material. The preservation as casts and moulds does not permit a specific identification.

Tentaculites sp. No. 4

Tentaculites aff. *tenuis* Sowerby; Gill, E. D., 1940, Proc. Roy. Soc. Vict. 52: 106.

DESCRIPTION: The shell is of medium size, up to 9 mm long, straight, sharply conical, with angle of growth about 5°. The cross-section is circular. The surface of the shell is covered with parallel, transverse, regularly arranged, rounded, raised annulations of two sizes. The coarser, of which two occur in the space of the apertural diameter, are separated by two to four finer riblets. The coarse annulations have a greater slope towards the aperture than to the apex. There is a suggestion of longitudinal striations across the transverse annulations and inter-annular areas on the moulds. Casts consist of clayey replacements of the shells. No internal structure can be seen in thin sections prepared from the casts, therefore no specific determination can be made from the material available: siltstone with a large number of empty moulds which once contained fossils, but with only a few fragments of casts remaining. Since plaster casts made in the moulds show coarse annulations separated by fine riblets, they can be placed in the genus *Tentaculites*, but no specific attribution can be made.

DIMENSIONS: Length of shell, up to 9 mm; width near aperture, 0·9 mm.

LOCALITY & MATERIAL: Cootamundra; blocks of siltstone in the collections of the Australian Museum, Sydney and the National Museum, Melbourne, presented by the late W. E. Williams of Cootamundra, N.S.W. Some specimens show layers of tightly packed empty moulds, in parallel arrangements. Other layers show empty moulds of tentaculitids arranged in a more random fashion (about 3 to the square centimetre) associated with other fossils. Associates are *Lingula adamsonii* Fletcher; *Grammysia obliqua* McCoy; *Leiopteria gregaria* Sherrard; *Nuculana striata* Sherrard; *Calymene* (*Gravicalymene*) *cootamundrensis* Gill. No outcrop containing the fossil-bearing siltstone could be found recently on the Temora road, 1½ to 2½ miles from Cootamundra, on Oak's Ck, the locality from which the collection is recorded (Gill 1940; Sherrard 1960).

AGE: Upper Silurian (Gill 1940).

REMARKS: Gill included *Tentaculites* aff. *tenuis* Sowerby in a list of fossils from Cootamundra accompanying the trilobite, *Gravicalymene cootamundrensis* Gill, when he was describing that species. McCoy (1855) suggested that *T. tenuis* may represent the young of *T. ornatus*. Since only empty moulds and a very few casts

of the tentaculitid from Cootamundra were available for study, the structure of the walls could not be determined. Details of the structure of the walls of *T. tenuis* Sowerby have not been published.

Genus **Volynites** G. Ljashenko 1957

The genus *Volynites* G. Ljashenko differs from the genus *Tentaculites* Schlotheim by the presence, on the external surface of the shell, of parallel transverse raised annulations of three different sizes. The internal wall of the shell has a step-like character.

aff. **Volynites russiensis** G. Ljash. 1957

(Pl. 38, fig. 8, 9, 13)

Volynites russiensis G. Ljasch. 1957, p. 96, Pl. III, fig. 1, 2.
Tentaculites russiensis G. Ljasch. 1958b, p. 24, Pl. IV, fig. 1, 2.

DESCRIPTION: The shell is of medium size (up to 10 mm long), straight, narrowly conical, of circular cross-section. The surface is covered with raised, parallel, transverse annulations arranged somewhat irregularly. In the tube-like apical section, the annulations are small and equi-dimensional. In the juvenile part of the shell, larger annulations are arranged in pairs, though the members of the pair are not often of the same size. Between each member of the pair, riblets may sometimes be seen on the inter-annular area, which, in this part of the shell, has a semi-circular surface. Approaching the aperture, large annulations are arranged singly, at a distance apart about equal to the apertural diameter. Between them are one or two smaller annulations and several finer riblets. Thus, there are three orders of size in the annulations and riblets. All large annulations have an almost symmetrical, rather sharply triangular outline. They project to a distance of about one-quarter the size of the internal diameter of the shell. The inter-annular areas have a flat surface in this section of the shell and are from two and a half to five times as wide as the annulations. Faint longitudinal striations can sometimes be seen on them making a cross-hatch pattern with the fine riblets.

The wall has a thickness of between $^1/_{12}$ and $^1/_{20}$ the diameter of the shell. Its internal surface faintly repeats the external sculpture of the shell, and sometimes has a stepped appearance (Pl. 38, fig. 9). Layering can be seen in the wall.

Near the apex there are about six annulations in 0·15 mm (the diameter in that section). This is followed by a section nearer the aperture where there are 2 to 3 coarse annulations in 0·5 mm (width of diameter in that section). Up to ten riblets occur in some inter-annular areas. The total number of coarse annulations is about 12. The internal cavity of the shell in the apical section is divided by transverse basin-shaped partitions (Pl. 38, fig. 8). In thickness, they are about 0·02 mm (¼ the width of the internal diameter in that part of the shell).

DIMENSIONS: Length up to 10 mm; width at aperture 0·8 mm, near apex 0·12 mm. Angle of growth 4-6°.

LOCALITIES: Tentaculitids from four localities are considered to belong to this species. These are Portions 26 and 53, Par. Eurimbula; Portion 3, Par. Cudal (Manildra Formation, Joplin *et al* 1952); and between the 1055 and 1155 ft levels in a bore at Louth. All are in the West of the State, the first two about 35 miles NNW. of Orange, the third about 25 miles W. of Orange, and the fourth on the Darling R.

REMARKS: The specimens described here show the three orders of annulations and the stepped wall which characterize *Volynites russiensis*, though the shell wall

of the N.S.W. forms is not so thick. Its width varies from $^1/_{12}$ to $^1/_{20}$ of the internal diameter of the shell. G. Ljaschenko's plates (1958b, Pl. 4) of *Tentaculites russiensis* show width of shell wall about $^1/_{10}$ the internal diameter of the apertural end. Ljaschenko refers to similarities between *V.* (*T.*) *russiensis* Ljasch. and *T. wenlockianus* Vine. *V. russiensis* Ljasch. is recorded from the Upper Ludlow of Western Russia.

Tentaculites russiensis was made the genotype of the new genus *Volynites* G. Ljaschenko 1957, but was described by her (1958b) as *Tentaculites russiensis* G. Ljasch. Fisher (1962) cites *Volynites* Lyashenko (Note: Fisher transliterates the Russian author's name thus) as a genus of the family Tentaculitidae Walcott 1886.

MATERIAL: Four specimens from the second locality given above, showing about 24 specimens of aff. *V. russiensis* in all. One specimen from each of the other localities, each with about 12 specimens. At least 20 specimens in bore.

Order DACRYOCONARIDA Fisher 1962

The species already described belong to the genus *Tentaculites* Schlotheim or seem to be affiliated to the genus *Volynites* G. Ljaschenko, that is they are thick-walled forms. In addition to these there are found, sometimes on the same slabs with thick-walled forms in N.S.W. (Pl. 38, fig. 13), thin-walled forms belonging to the Order Dacryoconarida Fisher 1962, Family Nowakiidae Bouček & Prantl 1960.

Specimens of this family in N.S.W. are incomplete proximally and sometimes only the casts are preserved. They are up to 5 mm long and 0·5 mm wide and show more or less regular swellings separated by contractions which are crossed by up to 20 discontinuous longitudinal striations. The walls are thin, varying between 0·01 and 0·03 mm.

Bouček (1964, p. 67) writes that 'it is not excluded that *Tentaculites matlockiensis* Chapman, redescribed by Gill (1941) which is recorded from Victoria, also belongs to the Family Nowakiidae.

In Czechoslovakia (Bouček 1964) and Thuringia (Zagora 1962, 1964) only thin-walled forms have been recorded. On the Russian Platform, the thin-walled forms *Viriatella, Crassilina* and *Styliolina* are recorded (G. Ljaschenko 1959) as occurring with thick-walled *Tentaculites* and *Dicricoconus* Fisher. *Nowakia karpinskii* G. Ljasch. is recorded from the Lower Eifelian with no accompanying thick-walled tentaculitids. Descriptions of tentaculitids from other countries do not give enough detail for comparison.

Bouček (1964, p. 157) as mentioned earlier, has come to the conclusion that though thin-walled forms of tentaculitids probably preferred living in deep sea zones, they could not have been entirely absent from benthonic, shallow areas where thick-walled forms lived. Such conditions must have prevailed in N.S.W. where thick- and thin-walled forms apparently lived together.

I concluded that the thin-walled tentaculitids from New South Wales are affiliated to *Nowakia acuaria* (Richter) from the Czechoslovakian Lower Devonian. They are similar in size, in shape and number per mm of the swellings and contractions of the shell wall when seen in longitudinal section. The wall in both is of about the same thickness and the angle of growth is equal.

The sculpture of the swellings and contractions is more pronounced than that seen in *Paranowakia* Bouček or in *Viriatellina* Bouček. Longitudinal striations are developed on the N.S.W. thin-walled tentaculitids to about the same extent as in

Nowakia acuaria (Richter) from Czechoslovakia. Other species of *Nowakia* found in younger Devonian formations in Czechoslovakia show much stronger longitudinal striation than that shown in specimens of *Nowakia* from N.S.W.

I sent specimens of *Nowakia* from New South Wales to Professor Bouček of Czechoslovakia in answer to a request from him. He does not agree that *Nowakia* from Ravine is conspecific with *N. acuaria* (Richter), but he thinks that it is almost the same as a species of *Nowakia* found in Czechoslovakia in the Uppermost Emsian (Zlichovian) horizon of the Devonian.

Genus **Nowakia** Gurich 1896

The members of this genus have short, narrowly conical shells which have a larger angle of growth than shells of the genus *Tentaculites* Schlotheim. The walls of the shells are thin and are transversely folded into rippling swellings and contractions which are repeated on the internal wall. Longitudinal striations are also present.

Nowakia aff. **acuaria** (Richter 1854)

(Pl. 38, fig. 13, 14, 15)

DESCRIPTION: The shell is small (up to 5 mm long), straight, acutely conical and of circular cross-section. It is usually black but sometimes bleached to white. The surface is covered with low, obtusely angled, rounded or pinched-out right-angled, transverse swellings separated by contractions which are up to twice as wide as the swellings (Pl. 38, fig. 14, 15). There are usually between 20 to 30 swellings in the length of the shell, at times inequidistant, three to five in the width of the diameter of the shell. They protrude from the shell surface about $^1/_7$ the width of the internal diameter of the shell. The wall is thin, about 0·01 mm. The internal surface of the wall of the shell is also rippled, exactly repeating the external sculpture. With high magnification a two-layered structure can be seen.

Longitudinal striations are noticeable on the external shell-surface. These make indentations on the summits of the swellings and can be seen on the contractions, but are not continuous for the length of the shell. There are 5 to 10 across the diameter of the shell.

DIMENSIONS: Length: up to 5 mm, but usually 2 to 3 mm. Incomplete proximally. Width at aperture up to 0·5 mm, usually 0·3 mm. Angle of growth: 7 to 12°.

LOCALITIES: Portion 57, Par. Selwyn, near Kiandra (Ravine or Upper Lob's Hole); Portion 103, Par. Ponto, near Wellington; Portion 65, Par. Taemas (Shearsby's Wall-paper), near Yass; Portion 26, Par. Eurimbula, about 35 miles from Orange.

MATERIAL: From the first and third of these localities about 30 specimens have been obtained; from the second and fourth localities about half a dozen each. All occur on the same slabs as thick-walled tentaculitids.

Stratigraphical Implications

An aim in this study was to commence the compilation of a stratigraphic table of tentaculitids from New South Wales. Such a table is necessary to determine the potential use of tentaculitids as zone fossils.

In the Hume Limestone at Hatton's Corner, Yass, in the Wenlock Formation of the Silurian, *Tentaculites ornatus* Sowerby has been identified. The dimensions of *T. ornatus* from Hatton's Corner are much the same as those of *T. ornatus* from Dudley, England, in the Wenlock, the type locality for Sowerby's species. *T.*

TABLE

The following table has been prepared, showing Tentaculitids described in this paper from their formations and presumed age assignments.

	Middle to Upper (Conolly, 1965)	Sandstone, Bogan Gate	*Tentaculites* sp. No. 3
DEVONIAN	Lower	1. Limestone, Ravine, Yarrangobilly R. 2. Wellington, Garra Formation (Strusz 1965) 3. Murrumbidgee Series, Taemas Stage *Spirifer yassensis* Limestone (I. A. Browne 1959)	*Tentaculites chapmani* n. sp. *Nowakia* aff. *acuaria* (Rich.)
DEVONIAN or SILURIAN		Limestone, Eurimbula	*Nowakia acuaria* (Rich.) aff. *Volynites russiensis* G. Ljasch.
SILURIAN	Upper	Calcareous shale, Louth bore Limestone, Cudal Manildra Formation (Joplin & others 1952) Siltstone, Cootamundra (Gill 1940)	aff. *Volynites russiensis* G. Ljasch. *Tentaculites* sp. No. 4
	Wenlock	Hume Limestone, Yass (Brown & Sherrard 1952)	*Tentaculites ornatus* Sowerby

ornatus described by G. Ljaschenko (1958b) from the Upper Ludlow of Western Russia is considerably larger.

aff. *Volynites russiensis* G. Ljasch. has been determined in New South Wales in a bore core at Louth, in the Manildra Formation of the Silurian near Cudal and also twenty miles to the N. at two localities in the Par. of Eurimbula. *Volynites* is listed (Fisher 1962) as occurring in the Lower Devonian and Upper Silurian.

Nowakia aff. *acuaria* (Richter) accompanies aff. *V. russiensis* in limestone at Portion 26, Par. Eurimbula. *N. acuaria* is characteristic of the Lower Devonian in Bohemia and it also rarely occurs in the uppermost Silurian (Bouček 1964). Tröger (1959) and Zagora (1962) recorded it from Upper Graptolite Slates (Lochkovian) and from the Tentaculites Nodular Limestone (Siegenian and Lower Emsian) of Thuringia.

The Garra Formation of the Devonian at Macquarie Park, Wellington, contains *Tentaculites chapmani* n. sp. and *Nowakia* aff. *acuaria* (Rich.). These two species have also been found together in the *Spirifer yassensis* limestone from the Taemas Stage of the Murrumbidgee Series of the Devonian. They both occur also in limestone at Ravine on the Yarrangobilly River near Upper Lob's Hole. As stated

earlier, according to Bouček (1964), *N. acuaria* (Rich.) is not found above the Lower Devonian in Czechoslovakia.

Tentaculitids examined up to the present from rocks of the Middle and Upper Devonian from N.S.W. are all casts and empty moulds and therefore cannot be specifically identified.

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Explanation of Plates

Plate 37

Fig. 1—*Tentaculites chapmani* n. sp. Ravine, Lob's Hole, Yarrangobilly R. Longitudinal section showing annulations, riblets, canals, layering of wall, internal surface of wall. Aust. Mus. No. F43436. × 50.

Fig. 2—*Tentaculites ornatus* Sowerby. Hatton's Corner, Port. 7, Par. Hume, Yass. Longitudinal section showing rounded outline of annulations, layering, canals, smaller shells inside larger. Aust. Mus. No. F15838. × 40.

Fig. 3—*Tentaculites chapmani* n. sp. Port. 208, Par. Warroo, near Taemas Bridge, Yass. Longitudinal section showing layering, internal surface of wall. Syd. Uni. Geol. Coll. No. 5892. × 30.

Plate 38

Fig. 4—*Tentaculites chapmani* n. sp. Port. 103, Par. Ponto, near Macquarie R., Wellington. Longitudinal section showing septa. Syd. Uni. Geol. Coll. No. 5896. × 10.

Fig. 5—*Tentaculites chapmani* n. sp. Holmes Station Paddock, Wellington, showing external surface. No. F688, Mining Museum, Sydney. × 8.

Fig. 6—Same as Fig. 4. Longitudinal section showing regular arrangement of annulations. × 10.

Fig. 7—Same as Fig. 1. Longitudinal section through tip of shell. Aust. Mus. No. F51893. × 25.

Fig. 8—aff. *Volynites russiensis* G. Ljasch. Port. 53, Par. Eurimbula about 35 miles NNW. Orange. Longitudinal section showing three sizes of annulations, septa. Transverse sections on same plane. Syd. Uni. Geol. Coll. No. 5895. × 10.

Fig. 9—aff. *V. russiensis* G. Ljasch. Port. 3, Par. Cudal, about 25 miles W. of Orange. Longitudinal section showing varying sizes of annulations and stepped character of internal surface of wall. Syd. Uni. Geol. Coll. No. 5890. × 18.

Fig. 10—*Tentaculites* sp. No. 1. ? Cavan, near Taemas Bridge, Yass. External surface. Syd. Uni. Geol. Coll. No. 5891. × 4

Fig. 11—Same as Fig. 10. Longitudinal section showing thickness of wall, internal surface, riblets on annulations and inter-annular areas. × 35.

Fig. 12—*Tentaculites chapmani* n. sp. Port. 208, Par. Warroo. Transverse section. Syd. Uni. Geol. Coll. No. 5892 × 30

Fig. 13—aff. *Volynites russiensis* G. Ljasch. and *Nowakia* aff. *acuaria* (Richter) on same slab. Port. 26, Par. Eurimbula. Syd. Uni. Geol. Coll. No. 5893. × 15.

Fig. 14—*Nowakia* aff. *acuaria* (Richter). Port. 26, Par. Eurimbula. Longitudinal section showing thinness of wall, rippling swellings and contractions. Syd. Uni. Geol. Coll. No. 5893. × 18.

Fig. 15—*Nowakia* aff. *acuaria* (Richter). Port. 65, Par. Taemas (Shearsby's Wall-paper). Longitudinal section. Syd. Uni. Geol. Coll. No. 5894. × 25.